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Leaching of an Acetanilide Herbicide, CP55097 in Soil Columns

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LEACHING OF AN ACETANILIDE HERBICIDE,

CP55097 IN SOIL COLUMNS

(TITLE)

BY

Regina K. Higgins

B.S., Eastern Illinois University, 1977

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1979
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
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LEACHING OF AN ACETANILIDE HERBICIDE, CP55097 IN SOIL COLUMNS

BY

REGINA K. HIGGINS

B.S. in Botany
Eastern Illinois University, 1979

ABSTRACT OF A THESIS

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Botany in the Graduate School of Eastern Illinois University

CHARLESTON, ILLINOIS
1979

ABSTRACT

The leachability of the acetanilide herbicide, CP55097 was determined using a soil column system. This herbicide, which is used as a preemergent against certain grasses and broadleaf weeds, was leached through four different soils (sandy clay, sandy loam, sandy clay loam and clay loam) using the following procedure. Plastic columns consisting of 8 rings (2 in. dia. x 1 in.) were assembled and their bottoms covered with cheesecloth. They were then filled with soil and prewetted with water to attain field capacity. Herbicide concentrations equalling 0, 1, 3, 6 lb/A were pipetted onto the soil surface and 0, 1, 2, 4 in/A of water was applied at an approximate rate of 1 ml/minute. The columns were leached for two days, then disassembled and the soil placed in styrofoam cups. The extent to which CP55097 leached through the soil columns was determined by an oat bioassay (<u>Avena sativa</u> var. Noble). After the soil dried for two days, 10 oat seeds were planted with the hilum end down. The plants were grown at a temperature of approximately 80 F and illuminated with cool white fluorescent light at 300 ft-c on a 15 hour photoperiod cycle. The plants were watered twice a day for a duration of eight days after which the shoots were weighed and the percent

germination recorded.

The organic matter and clay content of the soils was found to have a significant effect on the movement of the herbicide. In general, the herbicide moved less in soils with higher organic matter and/or clay content. Of the two, organic matter was more effective in reducing herbicide movement. Only in the low clay-low organic matter sandy loam was the herbicide leached throughout the eight inches of soil.

Statistically at a significance level of 0.05 all factors; soil type, CP55097 concentration, water application and soil depth separately and all interactions thereof significantly affected oat growth. However, the depth of leaching as determined by growth reduction, was not correlated with the concentration of CP55097 applied. Even though increasing concentrations of herbicide did reduce oat growth at specific depths, the maximum depth of observable effect was constant for each initial concentration tested.

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INTRODUCTION

To apply for registration of a pesticide from the Environmental Protection Agency (EPA), the manufacturer must prove that the product will not cause unreasonable adverse effect on the environment. If the EPA requests, a complete set of data supporting this claim must be presented before the pesticide is given label clearance (19). The compound 2-chloro-N-(ethoxymethyl)-6'-ethyl-o-acetotoluidide (hereinafter referred to as CP55097) has been reported as a preemergence herbicide for selective weed control in corn (*Zea mays* L.) and soybeans (*Glycine max* L.). This herbicide has proved to be slightly to moderately better than alachlor (Lasso) and metolachlor (Dual) in grass and broadleaf weed control in field studies (13). The purpose of this study was to examine the behavior of the compound in different soils varying in organic matter and clay content and gather supportive data required to gain CP55097 label clearance from the EPA.

REVIEW OF LITERATURE

Herbicides are applied directly to the soil as pre-emergence and postemergence treatments. The effectiveness of these applications is dependent upon the maintenance of phytotoxic concentrations in the upper 2 inches of soil where most weed seeds germinate. Conversely, since crop seeds also germinate in this area the herbicidal concentration must be low enough to permit establishment of the desired plant (14).

Leaching is an important factor affecting the herbicidal effectiveness of soil-applied herbicides. There are several factors which determine the extent a herbicide will leach through a given soil. Among these are water solubility of the herbicide, amount of water applied to the soil and the adsorptive relationships between the herbicide and the soil.

The greater the water solubility, the greater the leachability of the herbicide. Members of the thiocarbmate group which are sulphur derivatives of carbamic acid (NH_2COOH) have differing water solubilities. Molinate which has a water solubility of 912 ppm, leaches more readily through a given soil, as compared to vernolate and pebulate with water solubilities of 90 ppm and 60 ppm, respectively(7).

The substituted ureas such as, fenuron, monuron, diuron and neburon with water solubilities of 3850 ppm, 230 ppm, 42 ppm, and 4.8 ppm respectively, all exhibit the same relationship. Fenuron and monuron leach quite readily while diuron and neburon leach more slowly. However, monuron when compared to members of the triazine group shows resistance to movement despite its high water solubility. Triazines are heterocyclic nitrogen derivatives and with the exception of prometone (750 ppm) have relatively low water solubilities ranging from prometryne (48ppm) to atrazine (33 ppm) and simazine (5 ppm). In general, triazines are not subject to leaching (11, 14). Monuron with a solubility of 230 ppm would be expected to leach more readily than most of the triazines, however in soil column leaching experiments monuron, moves at about the same rate downward as atrazine and simazine (8). Thus, water solubility is only one factor affecting leachability.

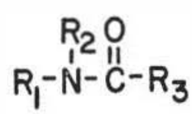
Herbicides vary in their adsorptive relationship to soil particles. The mineral particles found in soil range from sand particles (2.0-0.02 mm), silt (0.02-0.002 mm) to microscopic clay particles ($<$0.002 mm) (1). Herbicides are readily attracted to both organic and inorganic colloids (14, 24). The inorganic colloids are primarily clay particles with large surface area to volume ratios. The enormous surface area adsorbs many herbicide molecules, even in small amounts of clay. At recommended application rates, a high clay soil would need to have less than

0.0001% of its clay surface exposed to adsorb all herbicide molecules (1). The adsorptive capacity of clay particles is due to the bonds formed between the negative sites of the soil particles and positive cations found in soil; Ca^{+}, Mg^{+}, K^{+}, and Na^{+} constitute 99 percent of the exchangeable bases in soil. Of these four cations, Ca^{++} is adsorbed most strongly by clay organic colloids. The remaining 1% of the adsorptive sites, includes other cations such as Fe^{+++}, Co^{++}, Cu^{++}, Mn^{++} and Zn^{+}. The strength of the attractive force between a cation and a negative site on a soil colloid reflects the number of charges on the cations involved. The adsorptive sequence known as the lyotropic series is $Al^{+++} > Ca^{++} > Mg^{++} > K^{+} = NH_4^{+} > Na^{+}$. There has been some dispute as to where H^{+} belongs, but most often it is placed near the Na^{+} end of the series. It must be noted that this is a preferential adsorption sequence and is somewhat dependent on the concentration of each ion. In general, the negative sites on the soil colloid adsorb more of an ion early in the sequence, if the two are present in equal amounts (23). The measure of exchangeable cations that a soil can hold is the cation exchange capacity (CEC), usually expressed as milliequivalents of hydrogen per 100 g of dry soil (14).

In general the higher the CEC, the less leaching which occurs due to the bonding capacity of the herbicide to the soil. This is especially true of organic colloids which have high cation exchange capacities and are consequently able to tie up large numbers of herbicide molecules. The CEC of organic colloids can be from 4 to 20 times greater than some clay colloids (14). As a result, herbicides in organic matter soils often show little tendency to leach and application rates for preemergence weed control are usually higher in high organic matter soils (24). Large particled soils such as sand, have little soil colloids and most of the herbicide stays in solution and passes quickly through the soil. In general, sandy soils do not require as high a concentration of herbicide as do other soil types (14).

A major factor affecting the CEC of clay minerals is pH. As pH increases, the free cations are bonded into chemical compounds. As a result there are more free negative sites available and the CEC increases. Likewise if the pH decreases there is an abundance of cations tieing up the negative sites of soil colloids, thus the CEC decreases (10). Harris and Warren (9) studied herbicide adsorption of a high organic muck soil and bentonite. A given volume of herbicide was mixed with 0.25 g portions of soil. HCl was added in volumes to obtain the desired pH values. The herbicides tested were atrazine, monuron, CIPC (a carbamate), DNBP (a phenol) and diquat (an ammonium derivative). There was strong adsorption of atrazine by the bentonite at pH 4.1 (20 μmoles/g) however, there was little adsorption at pH 8.2 (2 μmoles/g). Adsorption by the muck soil was low at either pH values (pH 3.2, 4 μmoles/g, pH 5.3, 2.5 μmoles/g). There was almost total adsorption of DNBP by bentonite at pH 8.4. DNBP adsorbed only moderately well in the muck soil at pH 5.5 (3 μmoles/g. Thus, DNBP and atrazine are pH dependent. Monuron and CIPC were much less affected by pH, and only moderately adsorbed by either soil. Thus, pH as well as soil type may have an affect on herbicidal leaching.

The acetanilide herbicides are neutral polar acid amides which are bound to negative sites on soil colloids by H-bonding (12, 15). Their general chemical structure is as follows:



The R_3 group for all acetanilide herbicides is $-CH_2Cl$. The R_1 and R_2 groups vary with the herbicidal compound. Of the members belonging to this class of herbicides alachlor (Lasso), butachlor, CDAA, metolachlor (Dual), and propachlor are presently used in agriculture. The acetanilide herbicides are used to control seedlings of many annual grasses and broadleaf weeds. Most of these herbicides are used as preemergence or preplanting treatments.

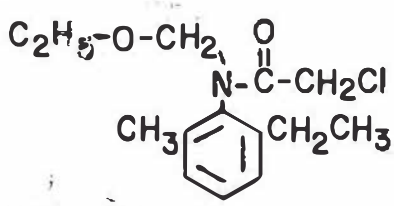
Parochetti (17) conducted greenhouse and field studies to determine the phytotoxicity of propachlor, alachlor, CDAA, pyrnachlor and atrazine in a variety of soils (0.2%-18.7% organic matter). The GR_{50} (amount of herbicide required to produce 50% growth reduction) values of CDAA increased with increasing organic matter levels. Under greenhouse conditions the GR_{50} values for CDAA at 3.9% and 18.6% organic matter was 4 times that of alachlor and 20 times that of propachlor. A greater amount of CDAA performed much like propachlor and alachlor. Pyrnachlor responded in the same way as CDAA in the field studies. The GR_{50} values for atrazine increased with increases in organic matter. There was a fourfold increase in the GR_{50} value for atrazine between 11% and 18% organic soils. It was noted, that the four acetanilide herbicides could be used with success on a variety of high organic matter soils, whereas atrazine should be used on soils with less than 10% organic matter.

In low organic matter soils, it has been reported that clay is the major site for cation exchange. Alachlor adsorption increases with an increase in clay content (22). Also, in a soil pH range of 4.1 to 12.1 alachlor adsorbed three times faster at a lower pH than a higher pH. Since agriculture soils do not have such extremes in pH, alachlor adsorption is probably not affected (12).

The leachability of acetanilide herbicides was investigated by Eschel (4). Soil columns were surface treated with 1 and 2 kg/ha. The herbicide was leached with 2 inches of water after reaching field capacity. The concentration of the herbicide at various depths was determined by sorghum growth reduction bioassay. The soils tested were clay, clay loam, sand and sandy loam, In all but the clay soil, the largest amounts of the herbicide were found in the 2 and 3 inch soil depth layers. Most of the alachlor was evident below 3 inches of soil. The extent of leaching in the clay soil was much less than in the other three soils.

CDAA leaching was studied by Gantz and Slife (6) in a silt loam soil (5.6% organic matter) and a sandy soil (0.1% organic matter) in soil columns. CDAA was distributed throughout the columns due to its adsorption to soil colloids. When leached with 10.2 cm of water CDAA leached completely out of the sandy soil.

CP55097 is the acetanilide herbicide studied in this paper. Its chemical designation is 2-chloro-N-(ethoxymethyl) -6'-ethyl-o-acetotoluidide with a chemical structure as follows:



CP55097 has a 57.9% active ingredient, a molecular weight of 269.8 g, and a water solubility of 398 ppm. In field studies, CP55097 was about twice as effective as alachlor in controlling some broadleaf weeds. In the case of smartweed and nutsedge, control was even better. In heavier soils there was no significant injury to corn or soybeans, however in lighter soils some injury was reported. This, injury was in the form of reduction in corn height and yield. Minnesota field studies in 1970, utilizing moderately high organic matter soils (5-7%) showed that CP55097 at rates of 0.75-3 lbs/A gave good weed control without crop injury to corn and soybeans. In small plot experiments, CP55097 was 1.5 to 2.0 times as active as alachlor on small seeded broadleaf weeds (ragweed, lambsquarter, and smartweed). The most effective rates for weed control were 1.5 to 2 lbs/A.

The margin of safety on corn and soybeans was less for CP55097 than alachlor. On low organic matter soils after heavy rainfall following application, slight stunting was observed at 1.5 lbs/A, moderate at 2 lbs/A and severe stunting and stand reduction was observed at 3 lbs/A. Alachlor showed no stunting up to 6 lbs/A. Conversely, in high clay and organic matter soils with low rainfall CP55097 revealed no injury to corn at 3 lbs/A and only slight stunting and stand reduction at 2 lbs/A. Alachlor had no effect at 3 lbs/A and only slight stunting at 6 lbs/A.

A series of experiments showed that as a preemergence treatment on fine to medium textured soils 1.5 lbs/A of CP55097, 3 lbs/A alachlor and 2 lbs/A metolachlor gave better control of Johnson grass and broadleaf weeds than equivalents of alachlor and metolachlor. Preplanting applications of 2 lbs/A gave 90% grass control by CP55097, 80% control by alachlor and 85% control by metolachlor. CP55097 also controlled broadleaf weeds more extensively than either alachlor or metolachlor. In all cases at rates of effective weed control, CP55097 showed no corn growth or stand reduction and only slight soybean growth reduction.

In general, CP55097 is significantly better in weed control than either alachlor or metolachlor. Only 1.5-2 lbs/A of CP55097 is equivalent to 3 lbs/A of alachlor or metolachlor. CP55097 has been found to be more susceptible to leaching than alachlor, but will persist in soil slightly longer.

All information concerning CP55097 was obtained from Lucinda Jackson, production development, Monsanto Agricultural Products Co.

METHODS AND MATERIALS

Plastic columns, 2 inches inside diameter by 10 inches deep were formed by placing eight 1 inch rings on top of one another and a ninth ring 2 inches deep on top of the eighth. The columns were held together with plastic electrical tape and the bottoms covered with cheesecloth to prevent loss of soil. The assembled columns were filled and packed with 8 inches of soil and then placed on elevated wire screen. Each column was prewetted with water and field capacity was attained when water ceased dripping from the columns.

Four soil types as shown in Table 2 were used in this study. Each soil was air-dried and sifted through a U.S. standard sieve with a 850μm pore size. Texture analysis was done according to the procedure described by Boucyoucos Hydrometer method (2); percent organic matter and pH was determined by the procedure described by Page (16); CEC was done according to Peech (18); and the trace metal analysis was determined by flame photometry and plasma source optical emission spectrometry (OES) (20).

CP55097 herbicide concentrations equalling 0, 1, 3, 6 lb/A were pipetted onto the soil surface. Glass wool was placed over the soil surface to prevent erosion and water equalling 0, 1, 2, 4 inches/A was applied at a rate of 1 ml/

minute.[1] Each treatment was done in triplicate.

After two days of leaching the columns were sliced into respective rings and the soil placed in styrofoam cups. The soil was allowed to sit and air-dry for two days after which 10 oat seeds (Avena sativa var. Noble) with a 95% germination rate were planted per container. Each seed was planted with the hilum end down in order to insure high germination. Seeds oriented otherwise germinate eratically (Table 1). The containers were placed in a room in which the temperature was maintained at approximately 80° F and illuminated with cool white fluorescent light at 300 ft-c on a 15 hour photoperiod cycle. After the seeds were planted the soil was moistened and watered twice a day for the duration of the experiment.

Eight days later the plants were harvested, percent germination and fresh weight of shoots was recorded and the replicates averaged.

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[1]the clay soil leached at approximately 0.25 ml/minute.

RESULTS AND DISCUSSION

A. Soil Analysis:

The soils chosen for this study varied significantly in mechanical and chemical composition. Texture analysis revealed the four soils to be of the following types: sandy clay loam, sandy clay, sandy loam and clay loam. There are notable differences between these soil types which should be considered (Table 2). The pH in most of the soils was alkaline, with the exception of the sandy clay (pH = 6.0). Organic matter content ranged from approximately 5% for the sandy clay loam and sandy clay to approximately 1% for the clay loam and sandy loam. The clay loam and sandy clay both had low cation exchange capacities (8 meq/100g, 2 meq/100g, respectively), whereas the sandy loam and sandy clay both had high CEC values (17 meq/100g, 32 meq/100g, respectively). Mineral analysis showed that calcium and magnesium content was considerably lower and potassium considerably higher in the sandy clay soil and likewise the sodium content was higher in the clay loam than any of the other soil types.

B. Leaching experiments:

The extent of CP55097 leaching was primarily dependent on the organic matter and clay content of the soil. Of these two, organic matter was the most effective in hindering leachability. As can be seen from Table 2, clay loam and sandy clay loam soils have approximately the same clay content (40%) whereas the sandy clay soil has 5 times the organic matter of the clay loam (sandy clay = 0.8%, sandy clay = 5.0%). As shown in Figure 1 and 2, CP55097 leached less in the sandy clay.

As mentioned above, the clay content of a soil can significantly affect the degree of leaching. CP55097 leached to approximately 3 inches in the sandy clay with 40% clay and to 5 inches in the sandy clay loam with 25% clay (Figures 1 and 2). Since the sandy clay loam and sandy clay contained about the same amount of organic matter, (Table 2) the reduced leaching in the latter soil appeared to be due to the higher clay content. CP55097 leached to 8 inches in the sandy loam which was to be expected since the organic matter and clay content of the soil was low (1.6% organic matter, 10.9% clay). These results are consistent with published results of other acetanilides (17).

The CEC is also closely correlated with herbicide movement. Those soils with high organic matter and/or clay contents have correspondingly higher CEC values. In general, less leaching occurs in soils having higher CEC values.

The degree of herbicidal leaching was independent of concentration (Figure 2). In the sandy clay at all concentrations (1 to 6 ppm), CP55097 remained in the first inch of soil, when 1 in/A of water was applied. This same trend was also observed at higher water application rates. The only difference being, the herbicide leached further down the soil columns.

Depth of herbicide leaching was greatly influenced by amount of water applied to the soil. Only in the sandy loam was there notable growth reduction observed throughout the column (Figure 3). When no water was applied (0 in/A) the herbicide persisted in the first inch of soil. With addition of 1 in/A of water leaching was observed to the third; 2 in/A leached the herbicide to the eighth inch of soil. This movement of herbicide through the soil columns, due to the increase in water applied, was evident in all soils, but to a lesser extent.

In support of the observed results, a four factor analysis of variance test and a Duncan's new multiple range test was run on an IBM 670 computer. The programs used were BMD08V and BMD07V respectively (3). Soil type, CP55097 concentration, water application and soil depth were tested separately first and then all possible interactions thereof. The results of the analysis of variance test (Table 7), showed that at a 0.05 level of significance all factors and all but one interaction was significant. Thus, the soil type, CP55097 concentration, water application and depth of leaching all separately and in combination affect oat growth.

However, the depth of leaching as determined by oat growth reduction, was not influenced by the initial concentrations of CP55097 applied to the soil. As would be expected, increasing herbicide concentrations did affect oat growth at specific depths, but the maximum depth of leaching was consistent regardless of concentration. All other factors, soil type, soil depth and amount of water applied affected the leachability of CP55097.

The Duncan's new multiple range test was used to compare each of the factors tested in the experimental design; soil type, herbicide concentration, water application and soil depths, as it relates to oat growth and leachability. Of the four soil types tested, there was no significant difference in oat growth between the sandy clay ($\bar{X}$=1.12) and sandy clay loam ($\bar{x}$=1.14), but there was a significant difference between the clay loam ($\bar{X}$=0.67) and sandy loam ($\bar{X}$=0.79). The sandy clay and sandy clay loam are high organic matter soils, which suggests that CP55097 is adsorbed and thus leaching is minimal, resulting in a high growth mean. Likewise, in the low organic matter soils; clay loam and sandy loam, leaching is somewhat more extensive, therefore reducing oat growth to greater depths in the columns and as a result lowering the oat growth mean. In terms of herbicide concentration, it would appear that concentrations in excess of 3 lbs/A are no more effective in reducing oat growth than 6 lbs/A since statistically there is no significant difference between these two. Water applications of 0 in/A and 1 in/A; 1 in/A and

2 in/A; 2 in/A and 4 in/A were not significantly different. in terms of oat growth. Also noted here, mean growth decreases from 0 in/A to 4 in/A of water applied. This indicates that as more water is added, the herbicide is leached further through the soil, therefore reducing oat growth. Statistically, there is a significant difference between the first three inches of soil, whereas in the last 5 inches there is no significant difference. When compared, the means show growth gradually increasing in the 1-3 inches and remaining about the same in the 4-8 inches. In general, this would indicate that CP55097 leached to about the third inch.[2]

Although there was a mineral analysis done of these soils, no correlation can be drawn between the concentration of an element such as aluminum found in a soil and the effect this has on the leachability of CP55097 through that soil.

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[2]CP55097 leached to the third inch in all soils except the sandy loam in which leaching occurred throughout the soil.

Table 1. Effects of position on oat seed germination per day after planting.

Orientation of 10 oat seeds	Pot number	Days after planting percent germination 2	3	5
Hilum end down	1	100	-	-
	2	100	-	-
	3	100	-	-
	4	100	-	-
	5	100	-	-
Hilum end up	6	0	0	0
	7	0	0	0
	8	0	0	0
	9	0	10	10
	10	0	0	0
Horizontal ¼" below surface	11	50	50	50
	12	70	70	70
	13	100	100	100
	14	50	50	50
	15	70	70	70

Table 2. Characteristics of the soils used in the leaching experiments.

Soil Type	Clay Loam	Sandy Clay Loam	Sandy Clay	Sandy Loam
Mechanical Analysis				
%Sand	24.3	74.6	55.5	76.2
%Clay	40.0	25.4	42.6	10.9
%Silt	35.6	0.5	1.9	12.9
Organic Matter (%)	0.8	4.8	5.0	1.6
pH	7.8	7.3	6.0	7.3
CEC (me/100g)	8.0	17.0	32.0	2.0
Mineral Analysis (ppm)				
Al	0.5411	0.4007	48.61	12.1
Ca	1306.	932.3	284.4	702.8
Cd	0.0126	0.0142	0.0226	0.0161
Co	0.0081	0.0269	0.0644	0.1513
Cr	0.0763	0.0506	0.0361	0.0619
Cu	0.0883	0.0546	0.2074	0.1499
Fe	0.7287	0.3927	3.8960	19.74
K	4.0	9.1	19.2	2.7
Mg	72.59	72.54	43.04	72.56
Mn	2.257	7.151	6.894	7.279
NO_3	<20	<20	<20	<20
Na	10.8	3.3	2.0	2.1
Ni	0.3613	0.0776	0.2417	0.1097
P	0.1	2.64	0.84	2.0
Pb	0.0740	0.0564	0.3560	0.3390
V	0.0344	0.0375	0.0980	0.0870
Zn	0.7948	0.7771	0.7713	0.8196

Table 3. Oat coleoptiles as percent of control in sandy clay soil.

Water

	1	2	3	4	5	6	7	8	
4 IN/A	98	103	104	102	94	101	105	113	
2 IN/A	116	106	106	101	100	100	104	102	0 lb/A
1 IN/A	105	119	96	111	85	119	121	110	CP55097
0 IN/A	96	100	103	97	102	94	102	106	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	70	72	85	104	106	90	95	105	
2 IN/A	70	82	98	102	94	100	93	105	1 lb/A
1 IN/A	67	100	99	106	101	102	95	103	CP55097
0 IN/A	78	106	86	107	96	94	109	106	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	62	58	65	91	96	101	101	105	
2 IN/A	73	63	100	100	102	102	102	100	3 lb/A
1 IN/A	44	77	102	100	102	102	102	111	CP55097
0 IN/A	64	87	108	108	102	95	102	104	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	52	52	37	81	95	99	106	107	
2 IN/A	39	43	88	98	101	102	101	100	6 lb/A
1 IN/A	32	66	99	87	111	102	96	106	CP55097
0 IN/A	28	90	100	98	101	107	101	97	

Depth of soil (IN)

Table 4. Oat coleoptiles as percent of control in sandy clay loam soil.

Water

4 IN/A	87	104	102	96	102	100	88	113	
2 IN/A	85	98	100	103	98	98	99	101	0 lb/A
1 IN/A	97	111	106	103	103	96	101	93	CP55097
0 IN/A	101	97	103	99	102	104	96	97	
	1	2	3	4	5	6	7	8	

Depth of soil (IN)

4 IN/A	72	77	88	103	104	104	114	102	
2 IN/A	58	90	98	108	101	109	96	109	1 lb/A
1 IN/A	47	102	109	97	109	106	100	103	CP55097
0 IN/A	83	113	100	116	112	105	114	108	
	1	2	3	4	5	6	7	8	

Depth of soil (IN)

4 IN/A	53	47	94	91	97	101	106	91	
2 IN/A	44	73	95	105	98	103	110	91	3 lb/A
1 IN/A	44	96	101	104	125	108	94	92	CP55097
0 IN/A	22	91	109	103	103	115	108	108	
	1	2	3	4	5	6	7	8	

Depth of soil (IN)

4 IN/A	53	39	79	93	97	35	111	105	
2 IN/A	32	66	108	99	103	93	113	105	6 lb/A
1 IN/A	32	105	107	111	108	119	119	116	CP55097
0 IN/A	16	110	110	108	103	91	115	103	
	1	2	3	4	5	6	7	8	

Depth of soil (IN)

Table 5. Oat coleoptiles as percent of control in sandy loam soil.

Water	1	2	3	4	5	6	7	8	
4 IN/A	95	99	104	98	102	106	98	104	
2 IN/A	96	104	98	96	96	101	100	103	0 lb/A
1 IN/A	91	100	99	97	90	94	111	110	CP55097
0 IN/A	97	100	97	101	98	98	99	101	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	91	81	101	80	84	92	85	86	
2 IN/A	75	78	71	84	90	90	101	105	1 lb/A
1 IN/A	80	68	72	99	102	101	95	94	CP55097
0 IN/A	40	100	101	88	106	96	86	100	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	82	84	71	75	56	54	56	84	
2 IN/A	71	59	51	46	78	101	104	102	3 lb/A
1 IN/A	53	43	52	94	95	106	97	100	CP55097
0 IN/A	18	84	99	100	92	95	93	98	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	65	64	72	57	38	37	51	68	
2 IN/A	50	45	37	39	64	92	100	91	6 lb/A
1 IN/A	41	21	32	87	99	97	99	100	CP55097
0 IN/A	7	79	94	99	100	93	98	104	

Depth of soil (IN)

Table 6. Oat coleoptiles as percent of control in clay loam soil.

Water

	1	2	3	4	5	6	7	8	
4 IN/A	116	108	100	97	90	81	92	95	
2 IN/A	93	118	106	114	95	104	100	96	0 lb/A
1 IN/A	116	112	114	107	113	94	118	88	CP55097
0 IN/A	104	112	112	118	115	101	98	71	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	92	88	65	73	70	97	73	101	
2 IN/A	78	71	61	113	103	97	105	82	1 lb/A
1 IN/A	61	48	73	104	114	100	107	97	CP55097
0 IN/A	57	126	109	110	105	108	92	104	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	73	70	53	44	35	84	107	97	
2 IN/A	47	42	38	116	79	94	108	105	3 lb/A
1 IN/A	34	23	95	95	112	118	58	82	CP55097
0 IN/A	104	110	90	114	117	108	107	103	

Depth of soil (IN)

	1	2	3	4	5	6	7	8	
4 IN/A	96	52	22	13	64	103	109	105	
2 IN/A	53	35	23	83	87	107	94	95	6 lb/A
1 IN/A	17	13	88	108	118	111	83	117	CP55097
0 IN/A	117	108	104	71	117	127	69	88	

Depth of soil (IN)

Table 7. Resulting F values from a 4 factor analysis of variance, testing soil type, CP55097 concentration, water application and soil depth as to their separate or combined effect on oat growth. Level of significance 0.05.

Factor(s)	F value	Significance at 0.05
I	1162.2	yes
J	148.7	yes
K	46.9	yes
L	176.2	yes
IJ	5.4	yes
IK	1.8	no
JK	5.4	yes
IL	8.6	yes
JL	27.7	yes
KL	15.2	yes
IJK	1.4	yes
IJL	2.3	yes
IKL	6.6	yes
JKL	3.4	yes
IJKL	1.7	yes

I = Soil type
J = CP55097 concentration
K = Water application
L = Soil depth

Table 8: Significance between factors using Duncan's new multiple range test. A line connecting 2 or more factors indicates that they are not significantly different at the 0.05 level. X = average oat growth in grams.

Soil type:

$\bar{X}$=	0.67	0.79	1.12	1.14
	clay loam	sandy loam	sandy clay loam	sandy clay

CP55097 concentration:

$\bar{X}$=	1.04	0.95	0.88	0.87
	0 lb/A	1 lb/A	3 lb/A	6 lb/A

Water application:

$\bar{X}$=	0.98	0.95	0.91	0.87
	0 in/A	1 in/A	2 in/A	4 in/A

Soil depth:

$\bar{X}$=	0.65	0.84	0.91	0.98	1.00	1.02	1.02	1.03
	1 in	2 in	3 in	4 in	5 in	6 in	7 in	8 in

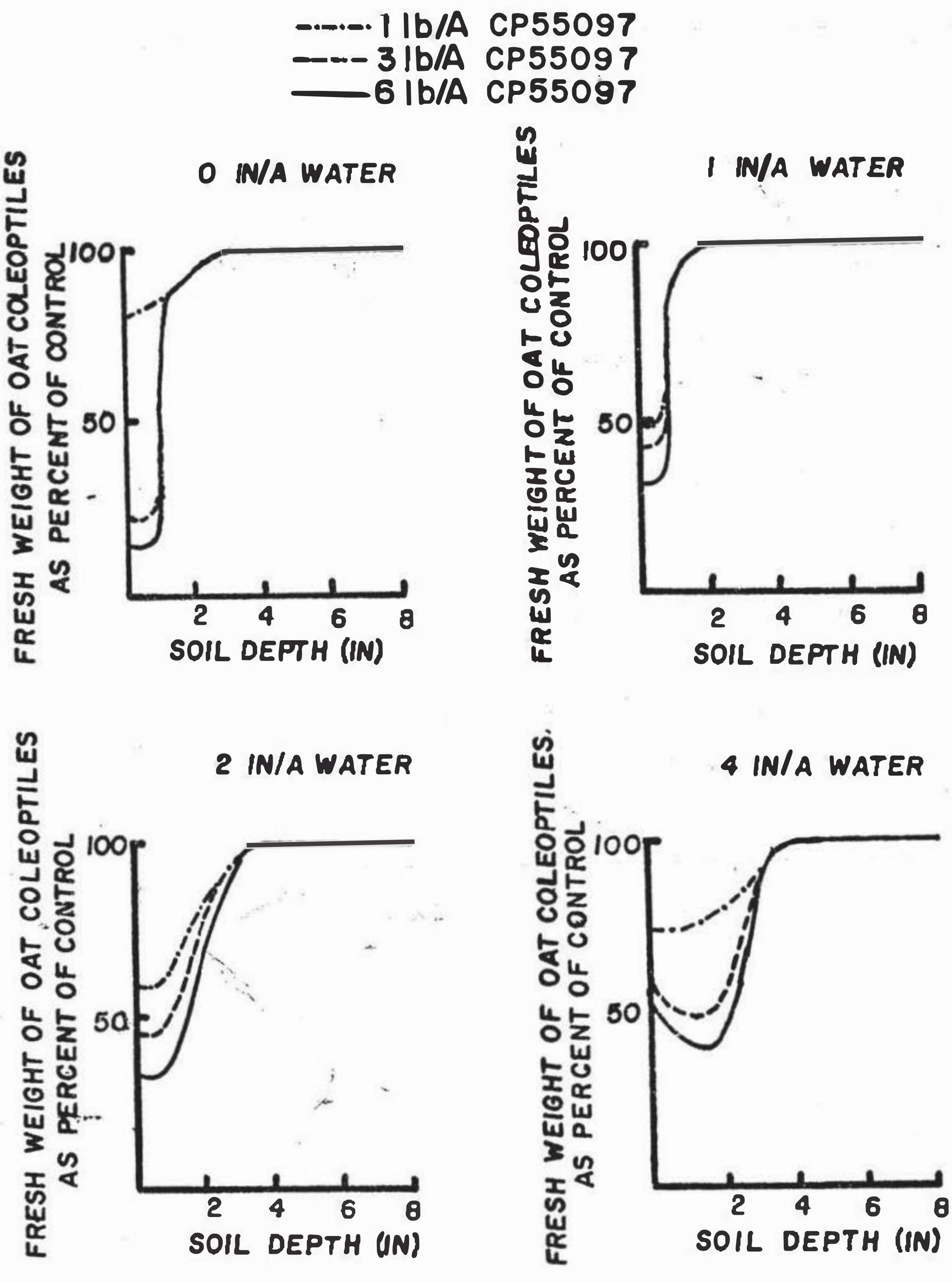

FIGURE 1. LEACHING OF CP55097 IN SANDY CLAY SOIL. O IN/A=NO WATER APPLIED, 1 IN/A=1 INCH/ACRE, 2 IN/A=2 INCHES/ACRE, 4 IN/A=4 INCHES/ACRE

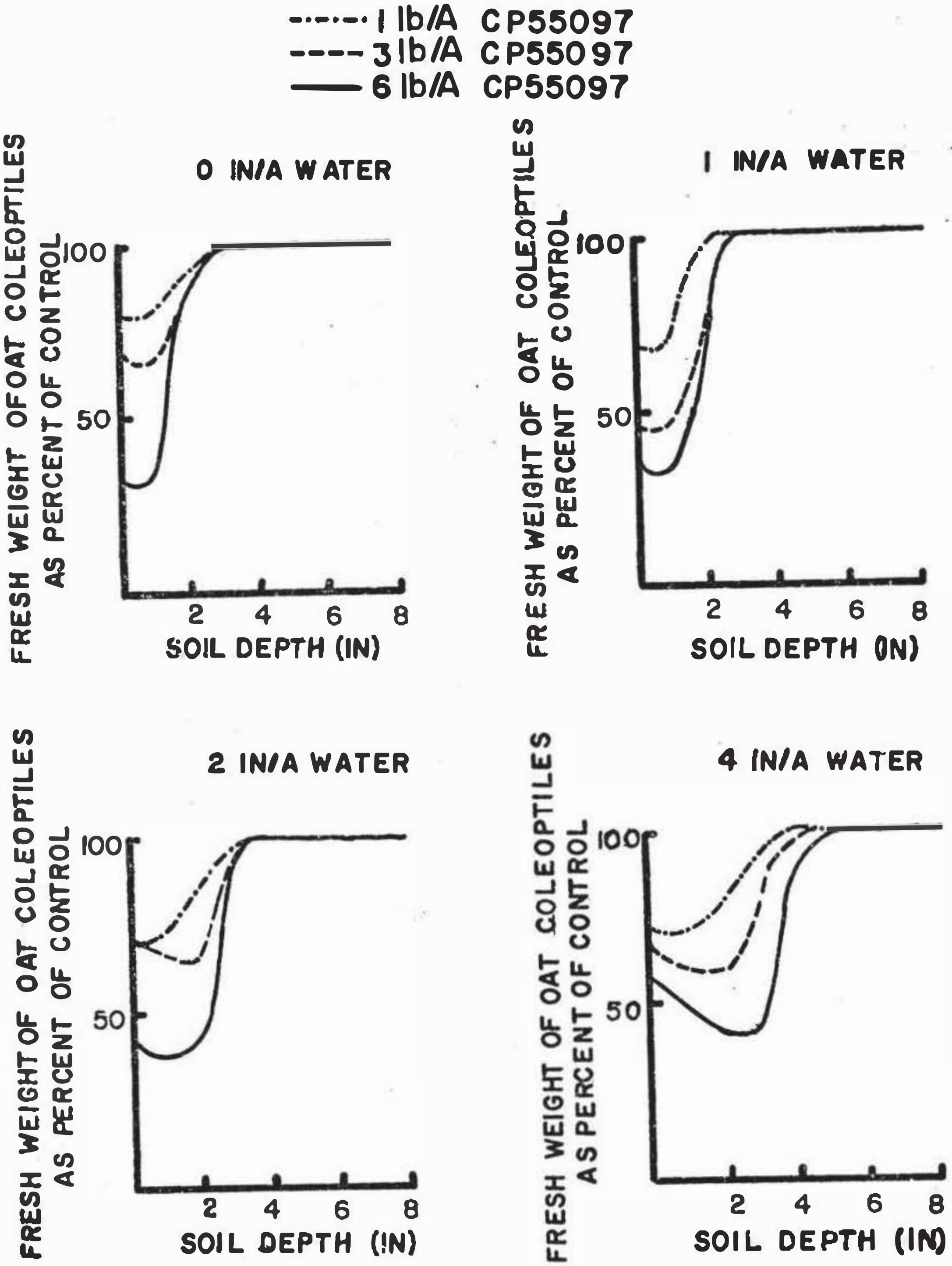

FIGURE 2. LEACHING OF CP55097 IN SANDY CLAY LOAM SOIL.
0 IN/A=NO WATER APPLIED, 1 IN A=INCH/ACRE,
2 IN/A=2 INCHES/ACRE, 4 IN/A=4 INCHES/ACRE

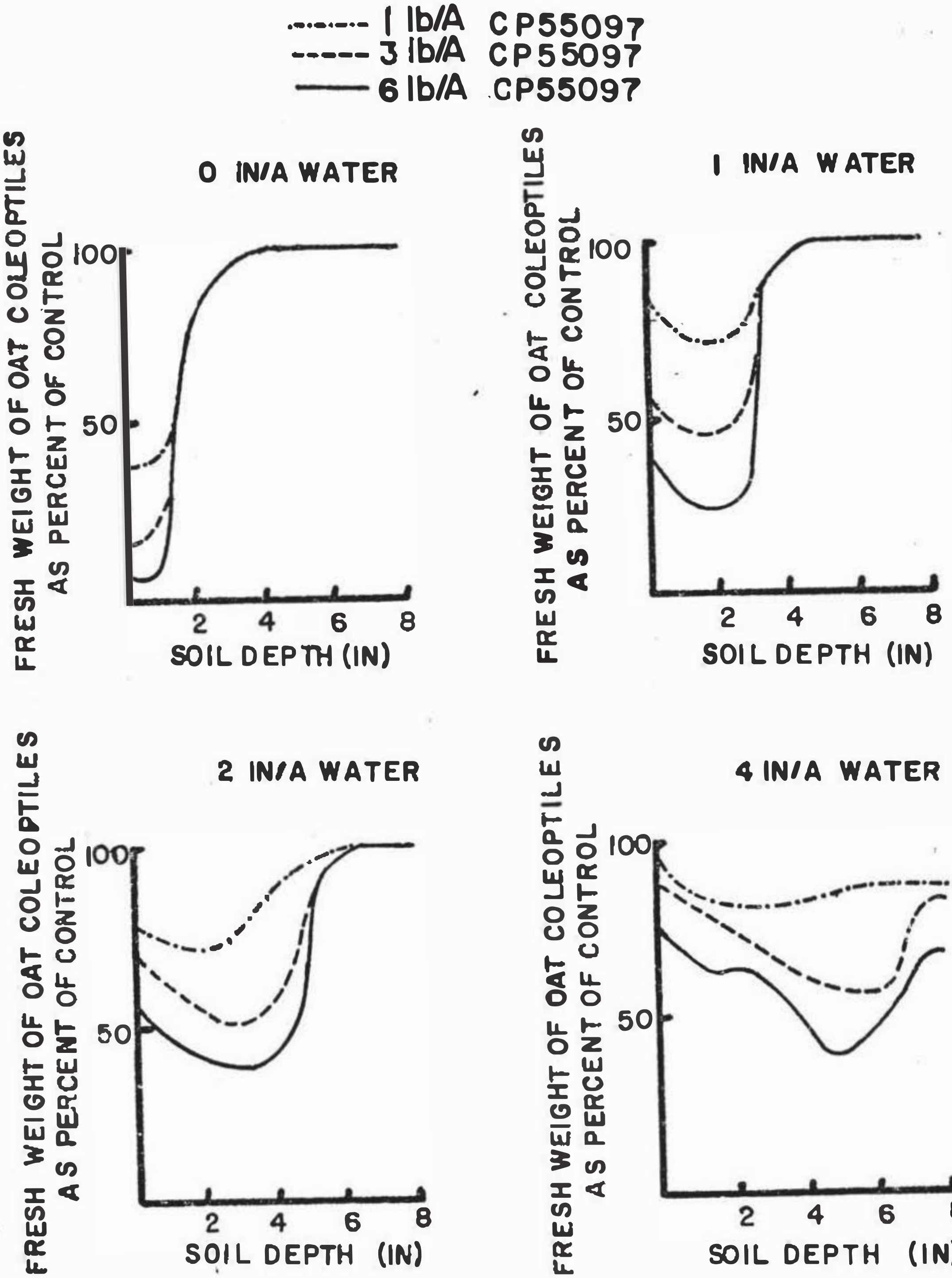

FIGURE 3. LEACHING OF CP55097 IN SANDY LOAM SOIL. 0 IN/A=NO WATER APPLIED, 1 IN/A= 1 INCH/ACRE, 2 IN/A=2 INCHES ACRE, 4 IN/A=4 INCHES/ACRE

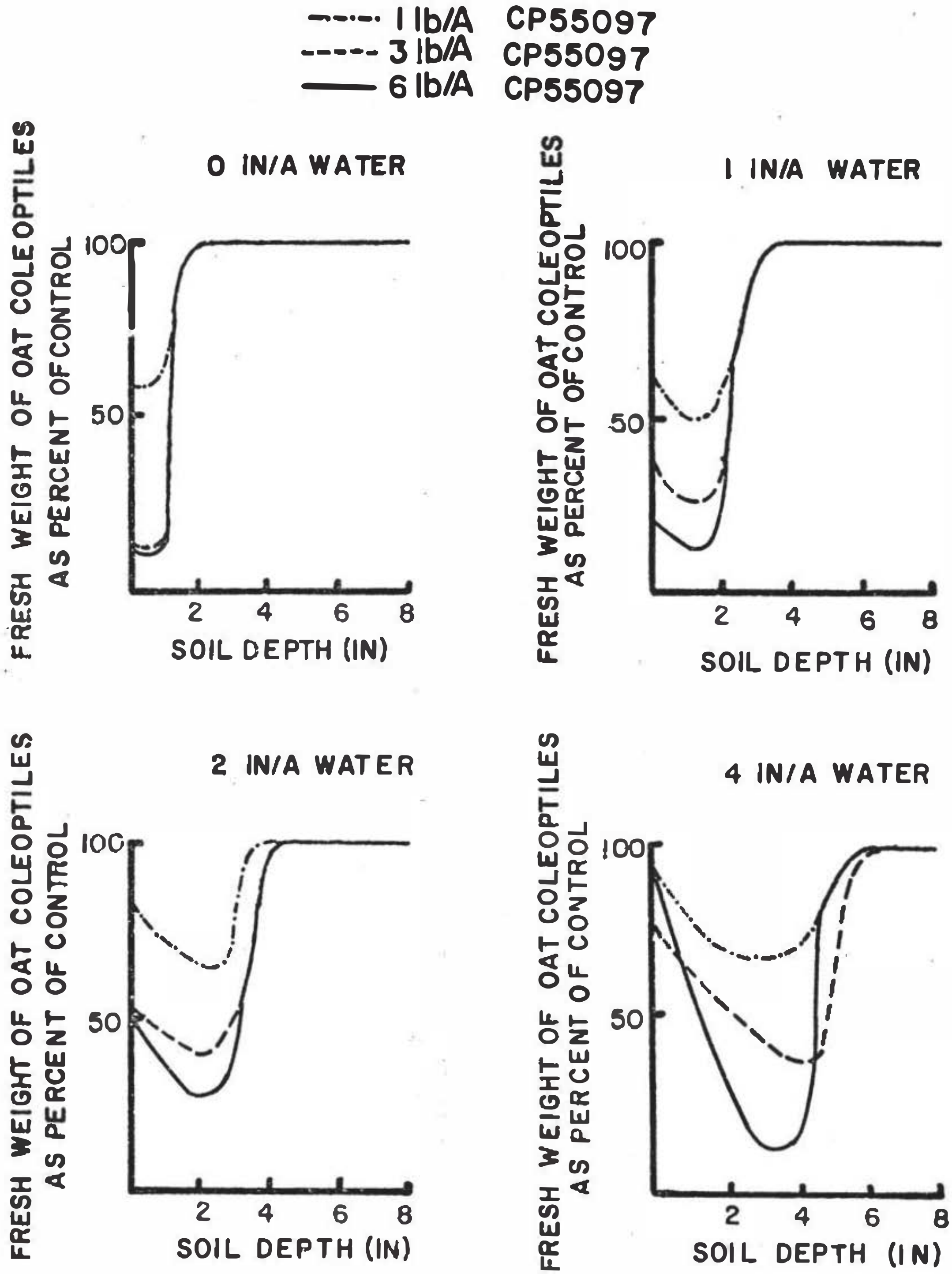

FIGURE 4. LEACHING OF CP55097 IN CLAY LOAM SOIL. 0 IN/A = NO WATER APPLIED, 1 IN/A = 1 INCH/ACRE, 2 IN/A = 2 INCHES/ACRE, 4 IN/A = 4 INCHES/ACRE

LITERATURE CITED

1. Baver, L. D. 1956. Soil Physics. John Wiley and Sons, New York. 489.

2. Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. Jour. 54: 464-465.

3. Dixon, W. J. (ed.) 1973. BMD Biomedical Computer Programs. University of California Press, London. 773.

4. Eschel, Y. 1969. Phytotoxicity, leachability and site of uptake of 2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide. Weed Sci. 24: 120-126.

5. Eschel, Y. and G. F. Warren. 1967. A simplified method for determining phytotoxicity, leaching and adsorption of herbicide in soils. Weeds. 15: 115-118.

6. Gantz, R. L. and F. W. Slife. 1960. Persistence and movement of CDAA and CDEC in soil and the tolerance of corn seedlings to these herbicides. Weeds. 8: 599-606.

7. Gray, R. A. and A. J. Weierich. 1968. Leaching of five thiocarbamate herbicides in soils. Weed Sci. 16: 77-79.

8. Harris, C. I. 1965. Adsorption, movement and phytotoxicity of monuron and s-triazine herbicides in soil. Weeds. 14: 6-10.

9. Harris, C. I. and G. F. Warren. 1964. Adsorption and desorption of herbicides by soil. Weeds. 12: 120-126.

10. Harrison, G. W., J. B. Weber and J. V. Baird. 1976. Herbicide phytotoxicity as affected by selected properties of North Carolina soils. Weed Sci. 24: 120-126.

11. Hilton, L.; Bovey, W.; Hull, M.; Mullison, W.; Talbert, R. E. 1974. Herbicide Handbook of the Weed Science Society of America. WSSA Herbicide Handbook Committee. Champaign, Il. 289.

12. Jordan, G. L. 1978. Environmental factors and soil relationships influencing the activity of acetanilide herbicides. Ph.D. Thesis. University of Wisconsin-Madison.

13. Jackson, Lucinda. 1978. Personal communication from Monsanto Agricultural Products Co. Decatur, Il.

14. Klingman, G. C. and F. M. Ashton. 1975. Weed Science: Principles and Practices. John Wiley and Sons, New York. 431.

15. Morrison, R. T. and R. N. Boyd. 1973. Organic Chemistry. Allyn and Bacon, Inc., Boston. 1258.

16. Page, N. R.; Thomas, G. W.; Perkins, H. F.; Rouse, R. D. (eds.) 1965. Procedures used by state soil-testing laboratories in the southern region of the United States, Bulletin No. 102. Southern Cooperative Series. Clemson, North Carolina.

17. Parochetti, J. V. 1973. Soil organic matter effect on activity of acetanilides, CDAA, and atrazine. Weed Sci. 21: 157-160.

18. Peech, M. 1945. Determination of exchangeable cations and exchange capacity of soils-rapid micromethods utilizing centrifuge and spectrophotometer. Soil Sci. 59: 25-28.

19. Ross, Steven. 1978. Environmental Regulation Handbook. Special Studies Division of Environment Information Center, Inc. New York.

20. Smith, Kenneth. 1978. Personal communication from Natural History Survey. Champaign, Il.

21. Steele, R. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Company, Inc., New York. 481.

22. Stevenson, F. S. 1972. Organic matter reactions involving herbicides in soil. Jour. Environ. Quality. 1: 333-342.

23. Thompson, L. M. and F. R. Troeh. 1973. Soils and Fertility. McGraw-Hill, Inc., New York. 495.

24. Upchurch, R. P. and D. D. Mason. 1962. The influence of soil organic matter on the phytotoxicity of herbicide. Weeds. 10: 9-14.